IS STANDING OFFICE ERGONOMIC?
EFFECTS OF WORKING POSTURE TYPE ON BODY DISCOMFORT AND PHYSICAL DEMAND

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Is standing office ergonomic?
Effects of working posture type on body discomfort and physical demand

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07. 01. 2016

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ABSTRACT

It seems that sedentary working with sitting posture for a long time is natural for office workers. It is not a surprising news that the participants who answered Ergotron's survey complained sitting posture. More than 70% of participants replied that they have to maintain sitting posture even if they do not want. It can be interpreted as standing is not a perfect solution for working environment. Many different alternatives were suggested instead of sitting office. Among them, standing office seems reasonable but still it has inevitable problems to use standing posture only. Stool is needed to explore that it could diminish the problem that standing posture have but the previous research did not examine much. The main goal of this study was to find out standing office is really ergonomic or not for office workers and could it be make sense to use stool as a substitute for office chair. In this study, meaning of ergonomics were focused on the physical comfort.

Twenty-eight healthy young adults were recruited for the experiment who use desktop or laptop frequently for studying or working. Task was performing documentation works with standing posture, sitting on stool and sitting on chair for 20-minutes duration. Prior to each task and after performing the task, subjective rating score was evaluated and circumference of each leg were measured. During the task, surface electromyography signal, movement of body segment and foot force were measured. Offered furniture like table, chair and stool were height adjustable and prior to task, participants could adjust all furniture segment and desktop monitor.

Study result proved that standing office is more ergonomic than sitting office. Participants kept body posture more neutral, following office ergonomics guidelines while standing. Viewing angle while sitting on stool and chair was lower than the suggestions in the guideline. Viewing distance was kept within a certain range while standing but for sitting on stool and chair showed increased trend compared to reference posture. Neck angle was kept straight only for standing posture. However, standing posture was not good for lower extremities to avoid muscle fatigue. It showed significantly higher than other conditions for gastrocnemius muscle. Stool seemed to have a possibility of being an alternative of office chair. It showed better performance on muscle activity and posture than chair condition. Chair condition caused higher muscle activation in upper trapezius area than other conditions. Stool condition caused almost same performance to chair condition except upper trapezius area. That is, it might be better to use stool for sitting posture than office chair. The result of this study suggests that combining standing posture and using stool might be the better solution than using only sitting on a chair for physical comfort of office workers.

DECLARATION

I, Hwayeong Kang, hereby that this thesis, which is approximately 12000 words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree at this Institute or any other Institute of Learning.

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PUBLICATIONS

Journal

Paper I

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Paper II

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Paper III

Kang, H., and Shin, G.* (2014). Hand usage pattern and upper body discomfort of desktop touchscreen users, Ergonomics 57(9): 1397-1404.

Conference

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Paper II

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Paper III

Shin, G., Lee, C., Lee, S., Kang, H. (2014) “Reliability evaluation of head position assessment methods”, Proceedings of the 1st Asian Conference on Ergonomics and Design – Jeju, Korea, May 2014 (ACED 2014).

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1. INTRODUCTION

1.1 Research Background

According to the Health and Welfare Ministry and the Korean Centers for Disease Control and Prevention, Korean spends 7.5 hours a day sitting which is more than sleeping, 6.8 hours (Figure 1). Sitting is inevitable part of office workers' daily life pattern. If someone asked to work for almost 8 hours with the same posture, they might choose to work with sitting.

Sitting has some benefits for prolonged working. Mörl and Bradl (2013) found that lumbar muscle activation level was very low while sitting. It was known that physical burden is transmitted by passive structures due to low activation of lumbar muscles while sitting. Even though sitting has benefits, it affects to workers' health condition negatively, too. It was known that the amount of time spent sitting is likely to confer health benefits. Prolonged sitting time jeopardizes to cardio-metabolic health even for whom exercise regularly (Dunstan, Howard, Healy, & Owen, 2012).

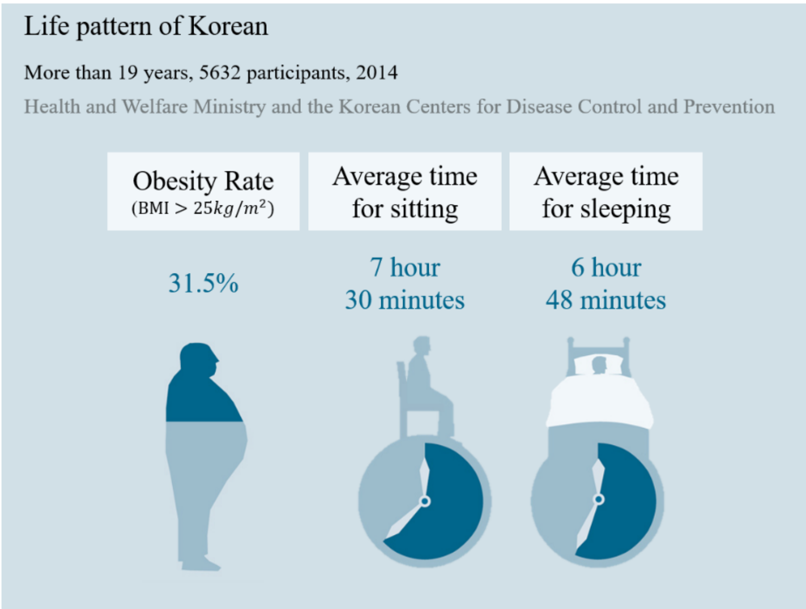


Figure 1. Life pattern of Korean. Retrieved from

http://news.donga.com/3/all/20160112/75846766/1. Copyright by dongA.com

Prolonged sitting at work and related problems have been reported frequently in reports or literature, and they indicate that office workers who used to maintain prolonged sitting can experience negative health outcomes due to their sedentary work habits such as increased risks of cardiovascular disease, type 2 diabetes and obesity (Wilmot et al. (2011); Hamilton, Healy, Dunstan, Zderic, and Owen (2008); Pereira, Ki, and Power (2012)). There is an evidence on relationships of prolonged repetitive working time and patterns of sedentary time with cardiometabolic risk biomarkers and health outcomes (Owen, 2012).

In addition to the metabolic diseases, prolonged sitting at work is known to cause musculoskeletal problems including low back pain (LBP) (Andersson, 1999). Gerr et al. (2002) found that muscular skeletal disorders/symptoms (MSD/MSS) on head, arm, neck and shoulder were common among computer users. Interesting point is that more than 50% of computer users reported as MSS during the first year after starting a new job. It indicates that prolonged sitting posture caused MSD/MSS severely who are not used to do sedentary work with bad posture.

Figure 2. Alternatives for sitting office

To address the issues from the sedentary work with sitting posture, previous research in office ergonomics has suggested alternative workstation settings or postures (Figure 2). They include the use of alternative chairs, treadmill, and/or standing desks. Among them, standing workstation has been a new trend and many offices in government sectors as well as industries have adopted standing desks at their work. However, using a standing desk has been motivated by recommendations from medical reports and public news articles without sufficient scientific evaluation of pros and cons of work in standing. Hence, a guideline for proper usage of standing office has to be explored.

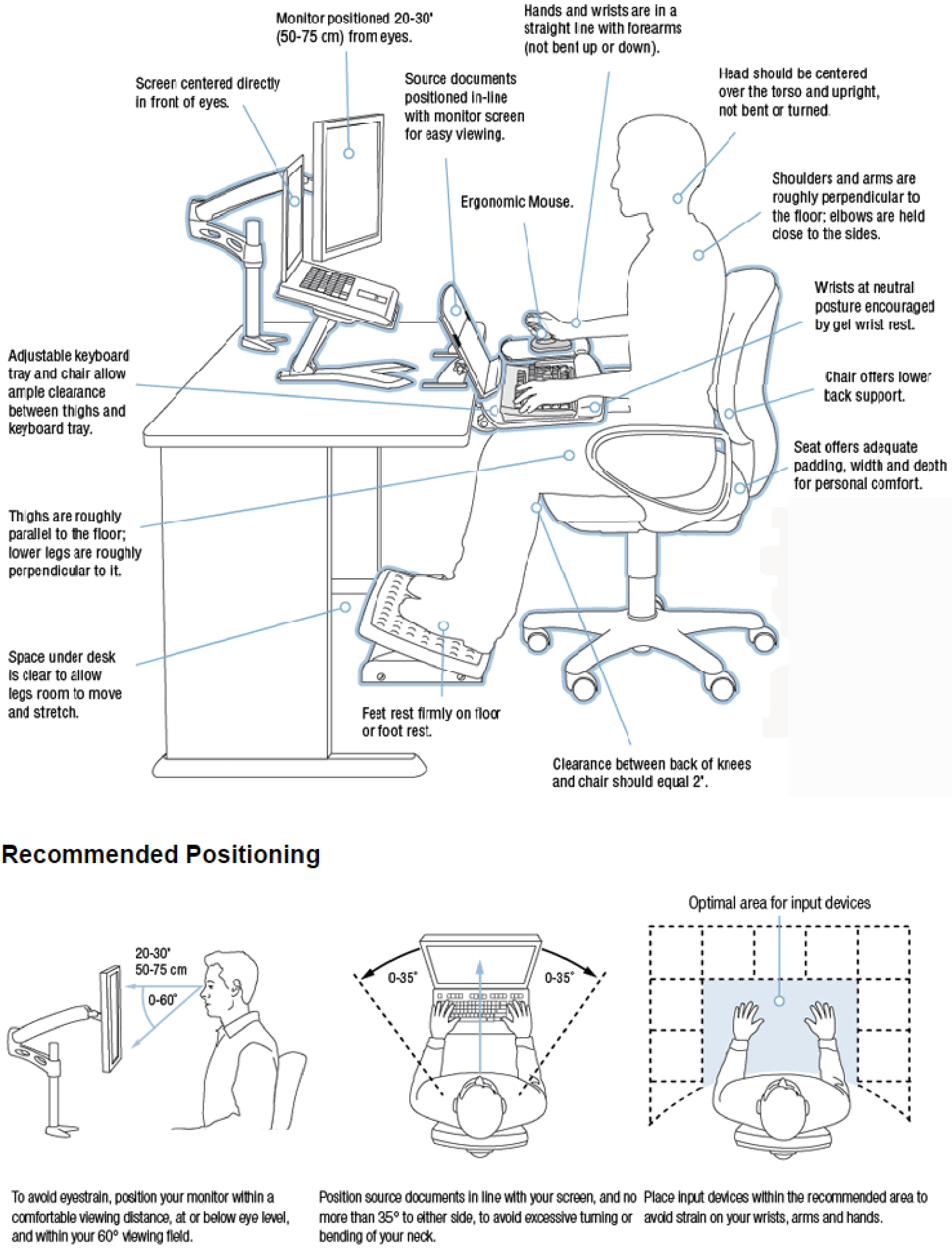


Figure 3. Sitting workstation guideline. Retrieved from http://solutions.3mnz.co.nz/wps/portal/3M/en_NZ/ANZ_Ergo/Home/LearnMore/Comfort/. Copyright 2016 by 3M.

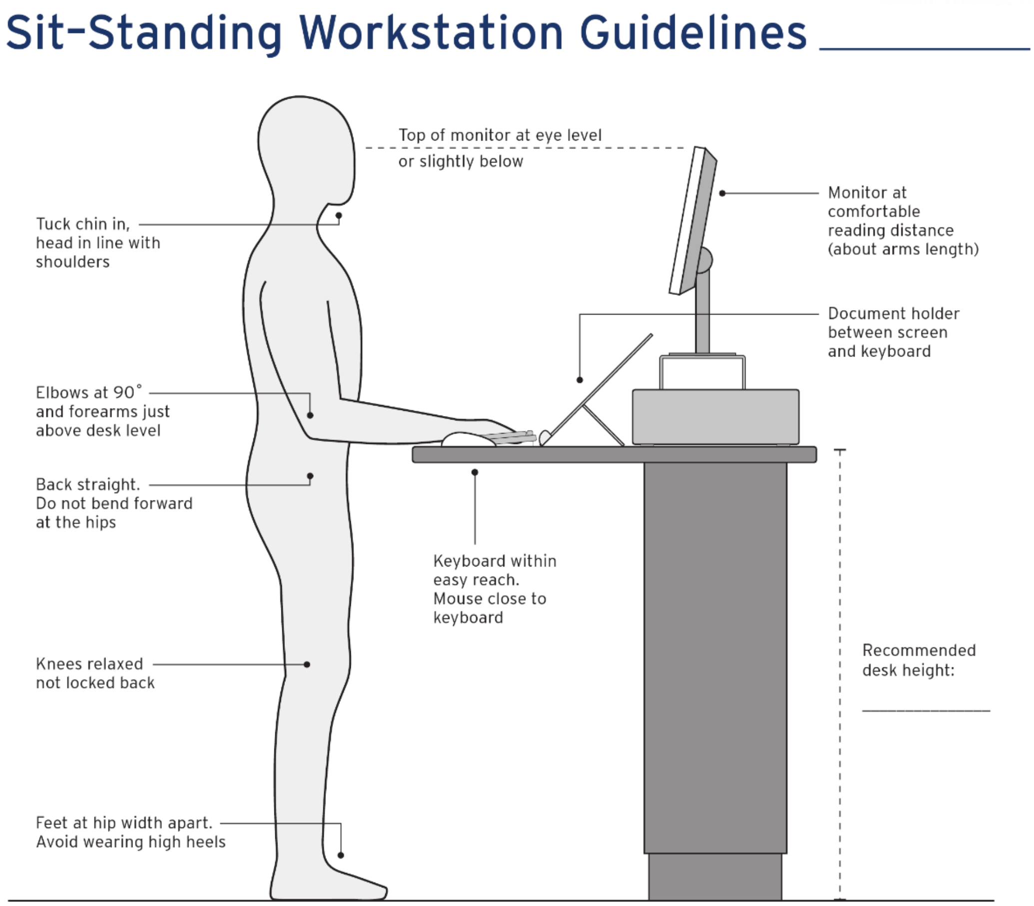


Figure 4. Sit-standing workstation guidelines. Retrieved from http://brsconsulting.com.au/sit-standing-workstation-guidelines. Copyright 2016 by BRS consulting.

According to guidelines for the design of standing workstations (ESA, 2009), there are many aspects that consider upper extremities such as table width and height, which are determined by the range of motion of upper extremities (Figure 4). However, recommendations for lower extremities are relatively few inversely from sitting office workstation guideline (Figure 3).

The situation also reflected standing workstation guidelines (Government, 2016). The only guideline for lower extremities is to keep head, neck, torso, and legs in line. To rephrase it, the guideline does not consider how standing could give burden to body segments and does not know how difficult it is to maintain the whole body as straight. Consideration of lower extremities has to include for standing office guideline. Therefore, new experiment design is needed based on an understanding of previous studies related to standing posture.

Marshall, Patel, and Callaghan (2011) designed an experiment to check muscle co-activation and rate of myoelectric fatigue during prolonged standing. Participants have to stand in constrained area (0.50m X 0.46m) and could not lean their body segments on the desk. The group who developed LBP showed higher increasing trend of Visual Analog Scale (VAS) score than the no-LBP group. That is, for LBP developed group, it is not recommended to use the standing office for a long time. It is needed to find out how the duration should be decided. The result showed that each 15-minutes performance showed significant changes. Thus, short-term observation study is needed to precisely check the significance of time effect. Co-activation result showed that when gastrocnemius (GM) muscle activates in both sides (left and right), participant recognized decrease of LBP level. However, the task was designed for bank teller (currency sorting), cashier (grocery store checkout), casino dealer (card dealing), assembly line worker (small object assembly) for this experiment.

King (2002) observed 1 week of 8-hours exposure for 4 types of condition (hard floor, floor mat, in-soles, insoles with mat) with working in standing. Only subjective rating score was collected to check fatigue. The questionnaire was asked including discomfort and general fatigue. Hard floor showed poorer performance significantly compared to other three conditions. It suggested that softer surface could reduce fatigue for prolonged usage. This field study could not control some factors like experiment task, table height, and others. Still, it has meaning that tries to find out how floor material condition could affect fatigue when prolonged standing. This study should be replicated with well-defined and controlled conditions.

Zander, King, and Ezenwa (2004) explored effects of floor conditions on fatigue. There were 3-floor conditions; wood block floor, anti-fatigue mat, and shoe insole. This field study was conducted for the 8-hours duration. Participants worked on an assembly line in factory and leg circumference were measured prior to doing working and after 8-hours of working by each participant using Gulick II tape after permanent marking at each segment following measurement guidance. Leg volume was calculated by using a mathematical formula. There was no significant change of leg volume. Thirteen workers participated in the experiment and their leg volume changes for each condition showed a different pattern. Insole type showed a higher change in leg volume compared to wood floor condition for most participants. It should be studied further with a shorter duration like one data per 1-hour.

Lin, Chen, and Cho (2012b) investigated effects of shoe/floor conditions on lower leg circumference and discomfort rating while standing for 4 hours. Gulick tape was used to measure leg circumference. Two-foot conditions (barefoot, sports shoes) and two-floor interfaces (concrete, soft) were tested. Barefoot/hard floor showed highest discomfort level but the discomfort increase and circumference increase showed the lowest. It was recommended to use sports shoes with mat floor even though discomfort change increased more than barefoot/hard floor combination because it showed lower discomfort and circumference length result in the overall protocol. The paper suggested taking a break at least once per 1-hour working. However, it needs more objectively measured data like EMG, movement trajectory data to support the result with scientific evidence.

Lin, Chen, and Cho (2012a) explored how leg movement affects leg swelling and discomforts in the lower extremities. Three movement types (no movement and two types of movement in figure 5) were performed each for 2-minutes.

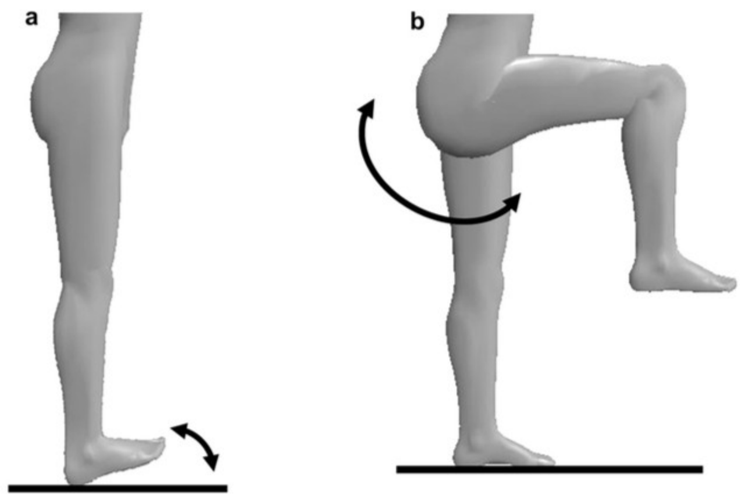


Figure 5. Type of leg movement for reducing the fatigue (Lin et al, 2012)

The movement could diminish leg circumference changes. No movement condition illustrated significantly higher leg circumference change. Also, leg circumference has a correlation with discomfort rating. However, performing stretching for each 2-minutes is not usual condition who works in an office and it can interrupt concentration on projects or assignments. Thus, it is needed to be explored to find out proper working-resting duration and ratio.

Antle, Vézina, and Côté (2015) compared sit-standing stool and standing postures to determine which one is better to use for a longer duration. EMG signal of upper extremities (gluteus medius (GM), rectus abdominis, external obliques (EO), lumbar erector spinae (ES), upper trapezius (UT), deltoid) was collected with discomfort rating. Participant performed box folding with 2 types of posture on separate days. Table height was constrained to follow workstation design guidelines for non-precision work (Grandjean & Kroemer, 1997). EMG root means square (RMS) value showed significant postural effects for left EO and left GM. Sit-standing stool relieved the burden on the lower back. However, the result shows only for the left side. To understand overall body burden correlation and standing mechanism, an additional measurement is needed to quantify standing condition. Also, the task was a folding box which is not a common task for office workers.

Karimi, Allahyari, Azghani, and Khalkhali (2016) explored whether shoe type could affect the lower leg muscle activity, volume change and discomfort rating during prolonged standing. Participants stood for 2 hours in each footwear condition, performing light assembly and mental task. Discomfort rating of leg showed the highest change in barefoot condition, flat-bottomed shoe condition and then unstable shoe condition in descending order. EMG signal decreased in most of lower extremities muscle in flat-bottomed shoe condition. However, discomfort rating and leg volume changes showed quite good performance in unstable foot condition. They concluded that unstable shoe could be a solution for prolonged standing. However, there was no sufficient evidence for prolonged usage for overall body segment. Thus, additional measurement for upper extremities and also for lower extremities is required to evaluate whether the flat-bottomed shoe is really ergonomic or not.

Previous studies showed trials of evaluation for prolonged standing and how it affects the upper body and lower extremities. However, there was no research that collected subjective and objective measurements together like subjective rating, leg circumference, and EMG signals. To quantify leg and foot movement, foot pressure could be one of the methods to observe the trend (Tanaka, Takeda, Izumi, Ino, and Ifukube (1999); Weerasinghe and Goonetilleke (2011); Yuk et al. (2010)).

Standing workstation needs to be explored more in terms of ‘ergonomic’. It usually advertised as an ergonomic product but there was no quantified evidence that can explain the product is really ergonomic or not. Prior to evaluating the standing office is ergonomic or not, it is important to define terminology of ergonomic. A definition of ‘ergonomics’, developed by the *International Ergonomics Association (IEA)* and adopted by the Human Factors and Ergonomics Society reads:

“Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments, and systems in order to make them compatible with the needs, abilities and limitations of people.”

To evaluate ‘ergonomics’ of ‘work in standing’, it is important to understand how users or office workers interact with elements of computer workstation when working in standing, how it is different from that of other work postures, and whether such differences would lead to better or worse health outcomes and work productivity. Therefore, this research was aimed to study physical interactions between people and computer workstation and potential benefits or risks of working in standing at the office. The interaction patterns and benefits/risks were compared with that of seated postures with a typical chair and a stool to see whether working in standing would be more ergonomic than working in sitting on a chair or a stool. The result of this study could contribute to suggest an ergonomic guideline for office working environment.

1.2 Research Rationale

There was an abundance of research which examined negative effects of prolonged sitting. Many creative suggestions showed the possibility to change office working posture. Exercise type like cycling or treadmill showed an increase of heart rate and energy expenditure but it diminished working performance like accurate mouse control and typing. Thus it could not be the best solution for working performance. Sitting on different chairs like a ball chair and a stool also showed good performance but ball chair showed no big difference in terms of body discomfort and stability (Schult et al., 2013). Still, it is needed to be compared between different office working postures by considering other factors like muscle effort and posture. Sit-stand workstation could be one of the alternatives and it showed significant changes during working (Alkhajah et al., 2012). It seems most suitable for office working is the standing office which provides a height adjustable desks and/or chair. Height adjustable can minimize the physical demand. Thus, standing office with stool could be one of the suggestions either.

Many researchers explored standing office to figure out whether it is a proper solution to reduce problems of prolonged sitting posture, and some problems while using the standing office for a long duration have been revealed. However, it has not been sufficiently studied whether such risks or benefits of standing work would be greater or lower than that of sitting work posture. In addition, it is not known whether the use of a stool could be an alternative choice between the sitting and standing postures that can overcome such problems while maintaining potential benefits of non-seated work posture.

Therefore, the aim of this study was to find out whether standing work posture in office is ergonomic or not, compared to traditional sitting work posture. Various measures of work posture and physical stress were compared between three different work posture conditions (stand, stool and chair) to quantitatively determine a more ergonomic work posture among them for office work. In this study, the definition of ergonomic was focused on the point of physical comfort and proper posture.

2. METHOD

2.1 Participants

Twenty-eight participants were recruited for this study. To minimize effects of job difference, only undergraduate students were recruited (Dowell, Yuan, & Green, 2001). All participants were healthy who had not experienced muscular skeletal disorders and had no skin allergic reactions on medical tape and alcohol in order to attach EMG sensors on skin. All participants usually performed documentation works regularly in office environments or study environments such as studying at the library with desk. Shoe size was controlled as 240 mm for females and 265mm for males. Most of the participants were right-handed. Only two participants were left-handers. Table 1 shows participant's characteristics.

Table 1. Participants' Characteristics

	# of participants	Age (years)	Height (m)	Weight (kg)
Female	14	20.4 (1.28)	1.629 (0.05)	58.2 (9.2)
Male	14	21.1 (2.03)	1.741 (0.04)	70.9 (8.3)
All	28	20.8 (1.71)	1.685(0.07)	64.6 (10.8)

2.2 Instruments

2.2.1 Motion capture system

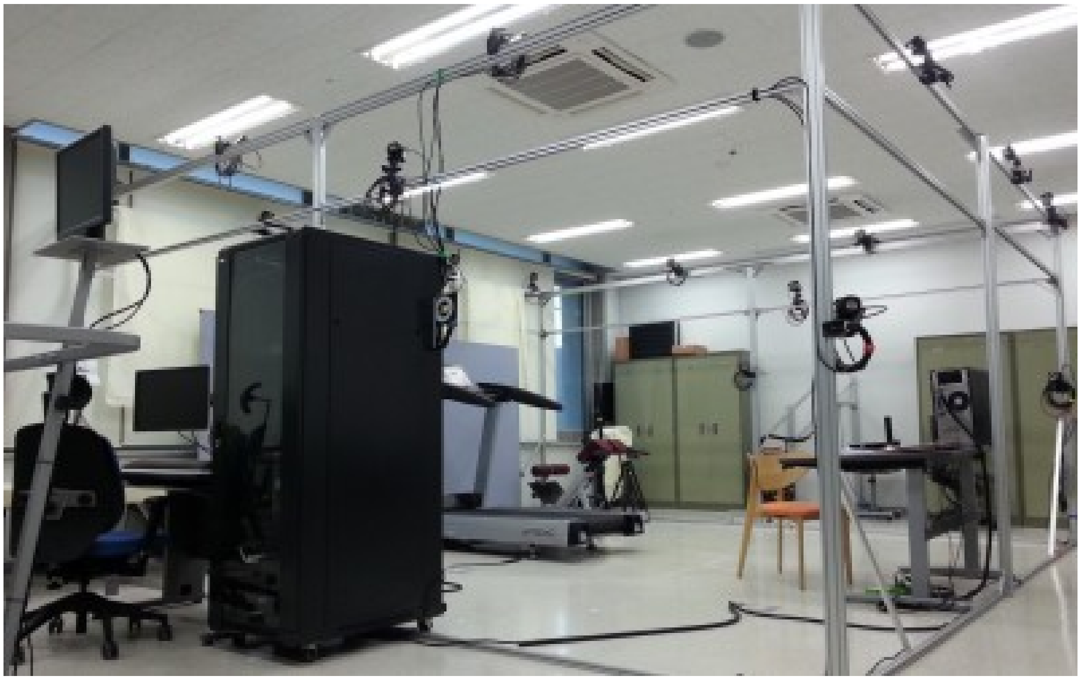


Figure 6. Motion Capture System

Optitrack Motion capture system (NaturalPoint Inc., Corvallis, OR) was used to detect human movement (Figure 6). Eighteen cameras were set on an aluminum frame and each camera projected infrared light and detected markers in three dimensions at a sampling rate of 50 Hz. Three axes were defined: medial-lateral direction set as X-axis, vertical direction set as Y-axis, and anterior-posterior direction set as Z-axis. Three rotation angles of each rigid body, as well as three coordinates of each marker, were tracked. Volume accuracy test was conducted before all experiments to check system stability. The experiment was conducted only the test showed the acceptable result.

2.2.2 Electromyography (EMG) system

Figure 7. Bagnoli Desktop EMG system

Bagnoli Desktop EMG System (Delsys Inc., Boston, MA) and non-invasive surface EMG sensors were used for recording muscle activity level (Figure 7). Sampling frequency was set at 2000Hz. EMG Works 4.0 Analysis software (Delsys Inc, Boston, MA) was used for data acquisition.

2.2.3 Plantar pressure measurement

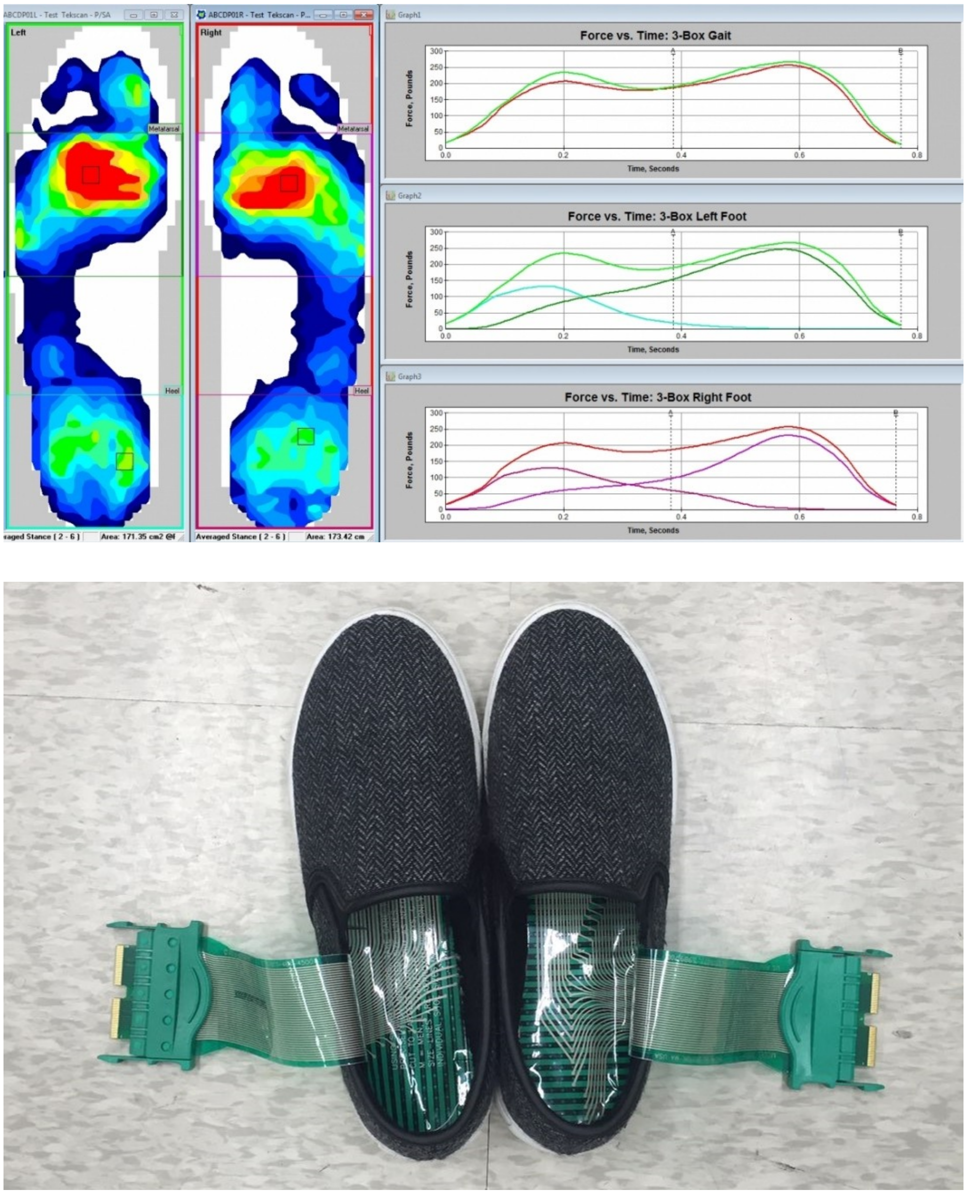


Figure 8. F-Scan software (up) and In-sole sensor (down)

F-Scan system (Tekscan, Boston, MA) was used to collect foot pressure data at a sampling frequency of 100Hz (Figure 8). F-Scan Research software version 6.32 (Tekscan, Boston, MA) was used for data acquisition. Ultra-thin insole type sensor (0.178mm, Medical sensor 3000E) was used to collect vertical reaction force data from each foot. It was attached to slip-on shoes. All participants used the same type of shoes, which were provided by the experimenter.

2.3 Experiment design and procedure

Figure 9. Experiment Setup

The experiment was conducted in a laboratory. Prior to the experiment, each subject was informed of the overall contents of the experiment. Participants who finally provided informed consent could join the experiment which was approved by Institutional Review Board of UNIST. In the laboratory, office work environment was implemented (Figure 9).

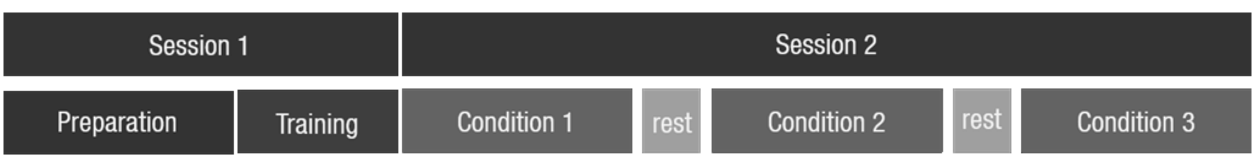


Figure 10. Protocol of the experiment

Experiment for each participant was conducted in two sessions (Figure 10). Session 1 was a preparation step. It consisted of skin preparation, some basic measurement and calibration steps for the experiment. Before attaching sensors, participant’s height and weight were measured. Session 2 included main tasks that tested three different office working conditions for 20 minutes each. Five minutes data were collected in each condition with 1-minute duration of five times, equal interval.

2.3.1 Muscle activity recording preparation

Participant's skin for EMG placement was cleaned by alcohol absorbed cotton pad to reduce electrical resistance and improve signal quality. EMG sensors were attached to the skin of gastrocnemius, upper trapezius, L2 level, and L4 level lumbar erector spinae muscles bilaterally (Figure 11). Sensors were attached to the skin using double-sided adhesive tape and additional elastic kinesiology tape.

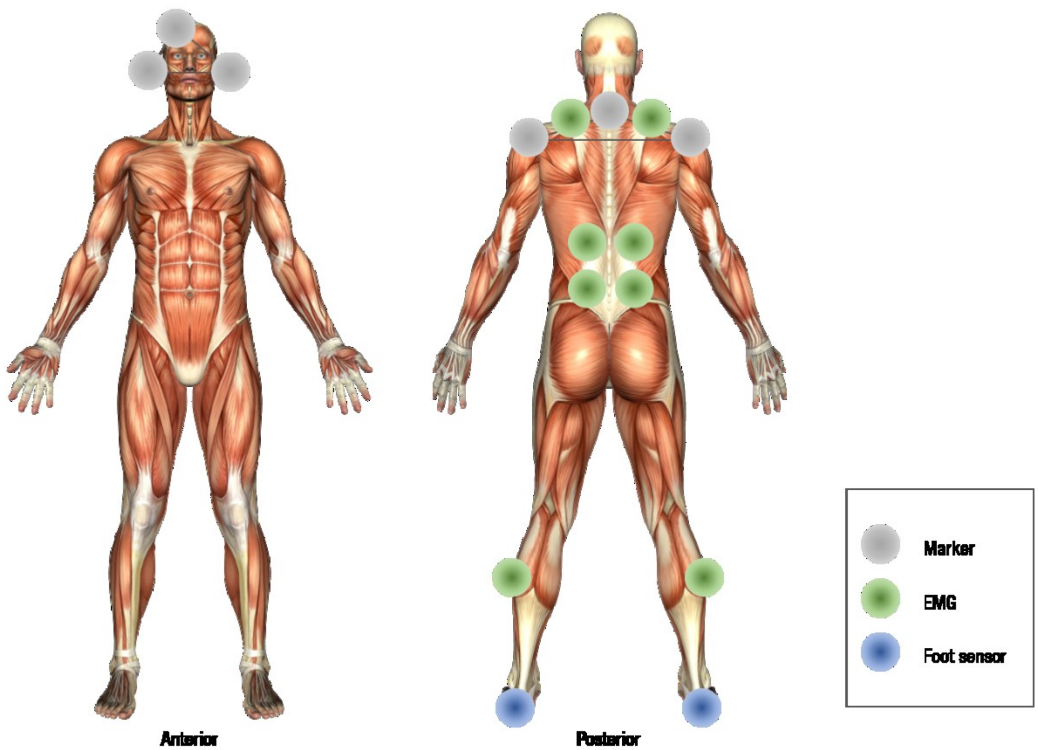


Figure 11. Location of attached sensors. Retrieved from http://www.delsys.com/products/software/emgworks/acquisition/. Copyright 2016 by Delsys.

EMG amplitudes of the maximum voluntary contraction (MVC) of the upper trapezius and reference voluntary contraction (RVC) of the lumbar erector spinae and gastrocnemius muscles were measured to normalize task EMG data. To prevent injuries during the MVC trials, practice session was performed to help the participant understand how to generate reliable signals without experiencing pain or fatigue. To measure the MVC of the upper trapezius, participant sat on a rigid chair and pulled a round-shape stationary bar up as hard as possible by shoulder elevation (Figure 12). To measure the RVC of the lumbar erector spinae muscles, a roman chair was used. A participant made the trunk parallel to horizontal on the roman chair and maintained the posture for 10 seconds (Figure 12). The RVC task of gastrocnemius was done by the tip-toe gate. Experimenter monitored a distance from the ground to participant's heel while the participant was asked to maintain the distance at 5 cm (Figure 12).

All MVC and RVC tasks were performed twice and the 1-minute resting period was given after each exertion for recovery. Data of more stable signal were used for normalization.

Figure 12. MVC and RVC measurement of muscles (Upper trapezius, L2 level and L4 level, Gastrocnemius)

2.3.2 Plantar force measurement preparation

Foot force sensors were inserted into the shoes and Velcro straps were used to fix the foot sensor adaptors to calve. Sensor status was checked when the participant stood up with the shoes, then foot sensor calibration was performed. For the calibration, participant stood still on one foot for 5-seconds and switched feet for calibrating both sensors.

2.3.3 Posture measurement preparation

Reflective markers were attached to the forehead, tragus (left and right), shoulder (left and right) and 7th cervical vertebra (c7) of the participant (Figure 11). From the markers, two rigid bodies were created: markers on the forehead, left tragus and right tragus represented the head rigid body, and markers on the C7, left acromion process and right acromion process represented the shoulder rigid body (Figure 11). Markers were also attached to the table, chair, and the monitor to create their rigid bodies. Center point of monitor rigid-body was set in the center of the monitor. Center point of the chair (and stool) rigid body was set on the seat reference point (SRP).

2.3.4 Main task

After the first session, the main task was performed. To provide comfortable workstation layout while performing the task, all furniture, and electrical devices were adjustable (Harrison, Harrison, Croft, Harrison, & Troyanovich, 1999). Table height was adjustable from 70cm to 110 cm from the ground. Height adjustable stool (Muvman, Aeris, Germany) was used for the stool condition, and an ergonomic office chair was provided (Aeron, Herman Miller, Zeeland, MI) for the sitting condition. Conventional LCD monitor (IPS236V, LG Electronics, Korea) was used, and its height and tilting angle was adjustable.

The main task was to replicate a document using the MS word software application, which was displayed on the left side of the monitor. There were 3 different documents (order was randomized) and the task required the participant to use both mouse and keyboard frequently. Before starting each task, the participant adjusted the workstation for his/her own comfort for the condition, and subjective rating scores were collected using a 0-10 scale. In addition, calve circumference was measured before and after each condition while standing with feet shoulder-width apart.

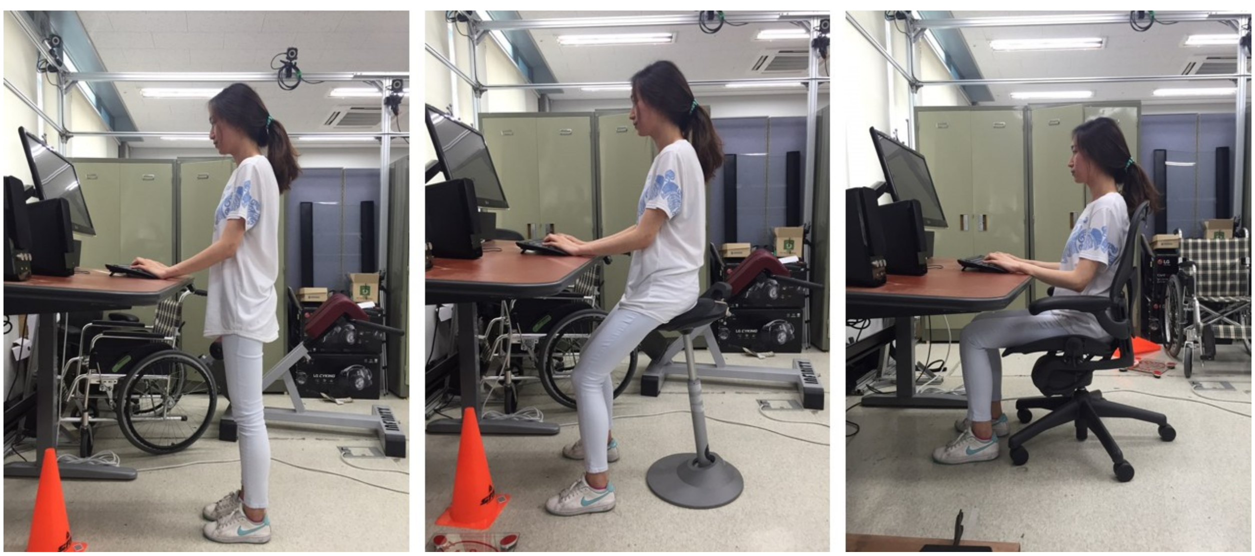


Figure 13. Three posture of experiment condition (standing, stool (sit-stand stool), sitting (office chair))

There were 3 posture conditions and each condition used different office furniture (Figure 13). Stand condition used desk only with no chair. Stool condition used a stool and the desk. Chair condition used an office chair and the desk. Before starting each condition, base posture was recorded for 10 seconds when the participant maintained a straight upright posture while looking straight forward with both arms in relaxed postures. Experimental data were collected five times in each condition to explore within-condition temporal changes in the EMG and posture of the participant.

2.4 Data processing and analysis

2.4.1 Movement tracking

Motive (NaturalPoint Inc., Covallis, OR) was used to collect the movement trajectory data. It was also used to refine the raw data and filter out unwanted marker data. For missing data points, 'swap' function and 'fill' functions were used to extrapolate near points. From the marker data, following variables were calculated.

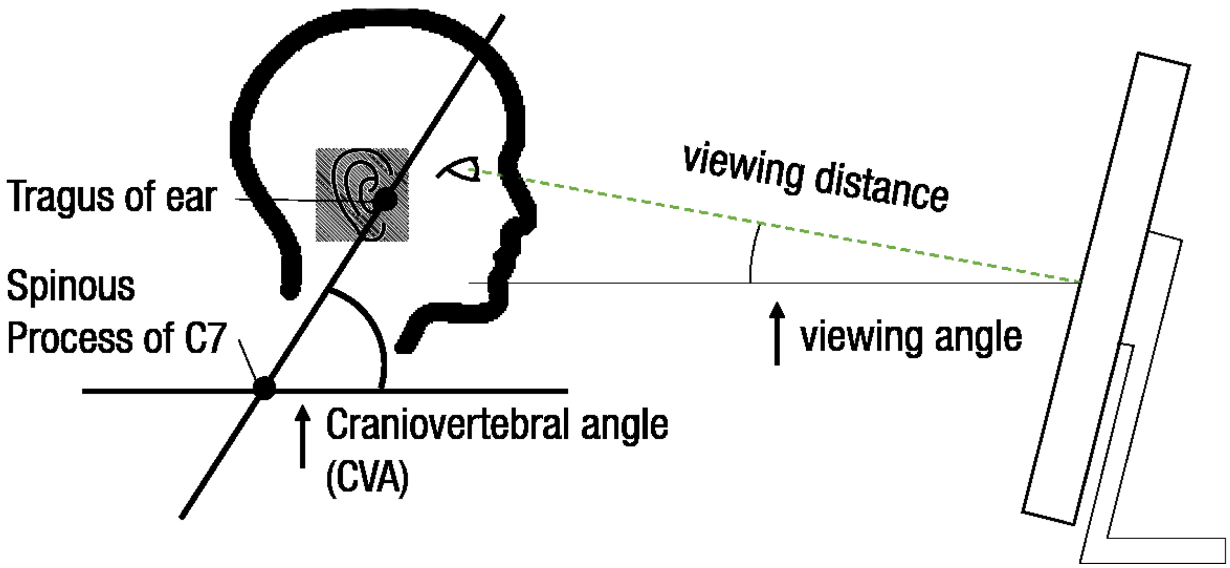


Figure 14. how to calculate viewing angle, viewing distance and craniovertebral angle

Viewing angle was calculated using below equation to determine the angle between the midpoint of the eyes and the center of the monitor:

$$Viewing\ Angle = \operatorname{atan}\left[\frac{(y - coordinate\ of\ Head) - (y - coordinate\ of\ Monitor)}{(z - coordinate\ of\ Head) - (z - coordinate\ of\ Monitor)}\right] \tag{1}$$

Viewing distance was calculated using below equation to compute the distance between the midpoint of the eyes and the center of the monitor (Figure 14):

$$Viewing\ Distance = \sqrt{\frac{\{(y - coordinate\ of\ Head) - (y - coordinate\ of\ Monitor)\}^2}{\{(z - coordinate\ of\ Head) - (z - coordinate\ of\ Monitor)\}^2}} \tag{2}$$

Craniovertebral angle was calculated by using this formula:

$$Craniovertebral\ Angle = \operatorname{atan}\left[\frac{(average\ of\ both\ side\ tragus'\ y - coordinate) - (y - coordinate\ of\ c7)}{(average\ of\ both\ side\ tragus'\ z - coordinate) - (z - coordinate\ of\ c7)}\right] \tag{3}$$

2.4.2. Muscle activities

EMG Works 4.0 Analysis software (Delsys Inc, Boston, MA) was used for data acquisition. Data filtering process was done by using MATLAB. After removing an increasing or decreasing trend, band-pass filter was applied to maintain selected range of frequency (10Hz to 500Hz). Notch filter was used to remove any electrical devices interference (60Hz in Korea). Linear envelope was then generated by applying the low-pass Butterworth filter.

For MVC or RVC data, the highest stable 1-second continuous dataset was selected and averaged. MVC or RVC data was used to normalize other EMG data. Amplitude analysis was done for all conditions. EMG data was averaged for each condition and task.

2.4.3 Plantar force

F-Scan Research software version 6.32 (Tekscan, Boston, MA) was used to process the plantar force data. Each foot's force data was averaged and the standard deviation was calculated. Laterality index was calculated using below equation to represent the amount of unbalanced standing status:

$$Laterality\ Index = \frac{abs(Left\ Force - Right\ Force)}{Body\ Weight} \times 100 \tag{4}$$

2.5 Statistical analysis

Minitab 16 (Minitab Inc., State College, PA, USA) was used to conduct statistical analysis. Analysis of variance (ANOVA) was performed to examine the effects of posture condition (3 levels; stand, stool, and chair). Tukey posthoc test was conducted to find the effect was significant or not. P-value was set at 0.05.

3. RESULTS

3.1 Subjective rating, leg circumference

Mean height of the computer table of each condition was represented by computing relative height to the participant's standing height:

$$Relative\ Table\ Height = \frac{desk\ height}{participant's\ height}$$

If relative table height (RTH) value is equal to 0.56, it means participant adjusted table height to 56% of his/her height. The relative computer table height followed the same trend for all participants. It was highest in stand condition and then stool and chair conditions in order (Table 2). Male participants tend to set table height higher than female group.

Table 2. Relative height of the computer table (unit : %).

	# of participants	stand (stdev)	stool (stdev)	chair (stdev)
Female	14	0.57 (0.03)	0.52 (0.04)	0.46 (0.03)
Male	14	0.59 (0.02)	0.54 (0.03)	0.47 (0.03)
All	28	0.56 (0.03)	0.51 (0.04)	0.45 (0.03)

Table 3. Subjective rating result (L.: left, R.: right)

body segment	stand (mean)	stool (mean)	chair (mean)	stand (stdev)	stool (stdev)	chair (stdev)	p-value
L.sh	*0.893*	*0.893*	*0.750*	*1.197*	*1.031*	*1.691*	0.888
R.sh	*0.929*	*1.000*	*0.821*	*1.538*	*1.540*	*1.722*	0.898
Neck	*0.893*	*0.964*	*1.143*	*1.343*	*1.261*	*1.433*	0.732
Upper Back	*0.929*	*1.857*	*0.929*	*1.438*	*2.272*	*1.303*	**0.03**
Lower Back	*1.607*	*1.714*	*0.786*	*1.663*	*1.584*	*1.397*	**0.034**
L.wrist	*1.571*	*0.821*	*0.893*	*1.834*	*1.156*	*1.133*	0.08
R.wrist	*2.000*	*0.750*	*0.821*	*2.091*	*0.967*	*1.124*	**0.001**
L.thigh	*0.929*	*0.714*	*0.393*	*1.538*	*1.150*	*0.916*	0.176
R.thigh	*0.893*	*0.750*	*0.250*	*1.315*	*1.206*	*0.799*	0.082
L.knee	*1.464*	*0.536*	*0.286*	*1.666*	*1.201*	*0.976*	**0.003**
R.knee	*1.536*	*0.571*	*0.321*	*1.795*	*1.425*	*0.983*	**0.005**
L.calve	*1.893*	*0.786*	*0.107*	*2.439*	*1.524*	*1.286*	**0.002**
R.calve	*2.000*	*0.643*	*-0.107*	*2.404*	*1.471*	*0.916*	**0**
L.ankle	*1.536*	*0.750*	*-0.143*	*2.063*	*1.430*	*1.297*	**0**
R.ankle	*1.571*	*0.786*	*-0.286*	*1.933*	*1.475*	*1.150*	**0**
L.foot	*2.821*	*1.429*	*-0.071*	*2.568*	*2.218*	*1.386*	**0**
R.foot	*2.786*	*1.357*	*-0.071*	*2.587*	*2.077*	*1.585*	**0**
Butt	*1.179*	*2.714*	*0.500*	*1.701*	*2.580*	*1.171*	**0.001**
L.circumference	*2.643*	*5.429*	*5.500*	*3.744*	*4.050*	*5.426*	**0.012**
R.circumference	*3.179*	*5.929*	*6.393*	*3.672*	*3.934*	*5.116*	**0.002**

Table 3 shows difference between pre-measurement and post-measurement of subjective rating score and leg circumference. Overall, lower extremities discomfort rating was comparatively higher while performing the task with standing posture than the others. However, for upper extremities, most body segments showed no significant difference between posture conditions. Right wrist showed higher discomfort rating while standing than other conditions.

Participants reported that sitting on office chair was more comfortable for lower extremities and relieved tension on the lower extremities than the others, but leg circumference increased more than the other two conditions. Butt discomfort rating scored highest while using stool. It was even higher than standing condition. It is opposite to the results of lower extremities like thigh and calve.

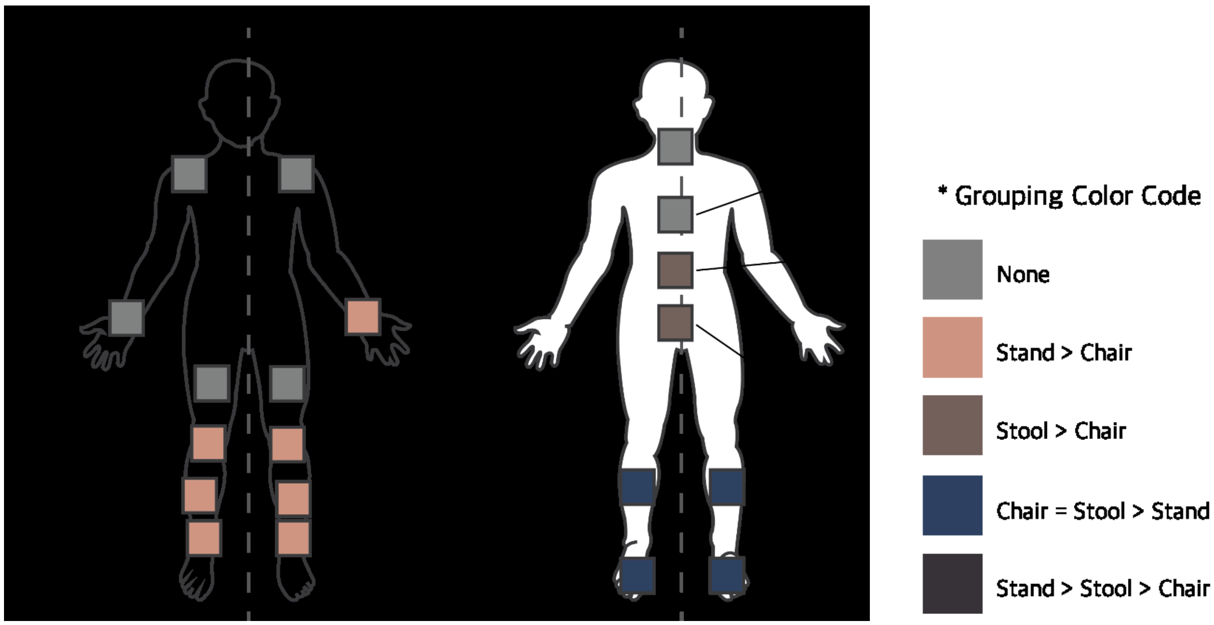


Figure 15. Grouping result of discomfort rating

Figure 15 shows grouping result of discomfort rating. Color indexing showed same grouping result. Grouping result was categorized into 5 types that was mentioned above (none; stand > chair; stool > chair; chair = stool > stand; stand > stool > chair;). Calve and leg circumference showed same grouping result. Thus, only one color indexing box was used.

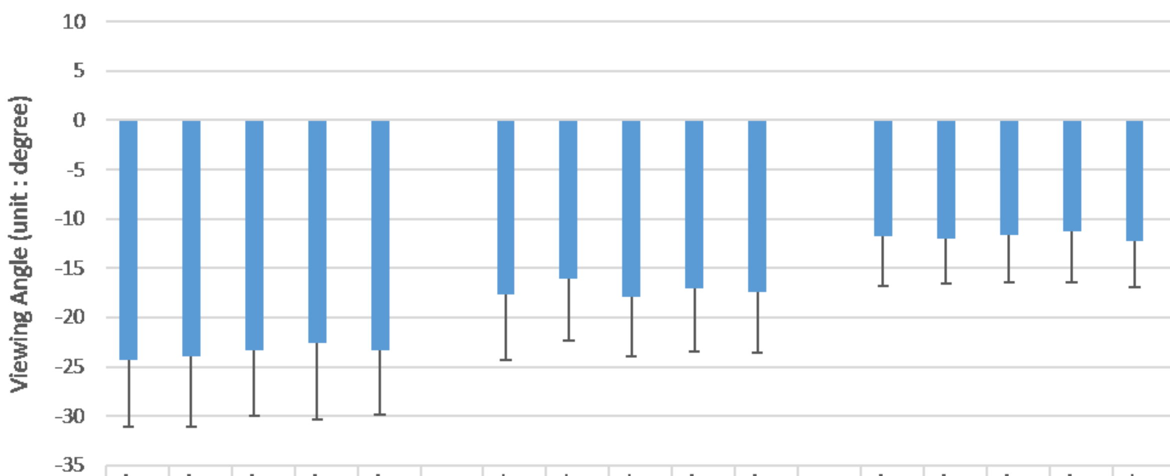
For upper extremities, there were no significant differences between groups except right wrist and lower back. There were no significant differences in the shoulder, neck, upper back and left wrist. Right wrist and knee discomfort changes were highest in stand condition and no big differences between stool condition and chair condition was found. Lower back showed significant difference for all groups (stand > stool > chair). For the lower extremities, posture affected discomfort rating and circumference measurement result. Thigh, calve, ankle and foot discomfort change increased for stand condition, stool condition, and chair condition. On the contrary, neck discomfort change increased for chair condition, stool condition and stand condition. Butt discomfort change was highest in stool and no big differences between stand and chair conditions.

3.2 Movement tracking

Three types of quantified movement tracking data were evaluated for each posture condition. Posture difference significantly affected upper extremities posture. However, there were no time effect in each condition.

Table 4. posture change data table

	stand (mean)	stool (mean)	chair (mean)	stand (stdev)	stool (stdev)	chair (stdev)	p-value
Cranio-vertebral angle	*65.406*	*64.684*	*61.860*	*2.327*	*5.955*	*5.726*	**0**
viewing angle	*-23.491*	*-17.227*	*-11.804*	*6.917*	*6.272*	*4.755*	**0**
viewing distance	*0.571*	*0.581*	*0.565*	*0.126*	*0.077*	*0.096*	0.622



	time 1	time 2	time 3	time 4	time 5	time 1	time 2	time 3	time 4	time 5	time 1	time 2	time 3	time 4	time 5
mean	-24.3	-23.9	-23.3	-22.6	-23.3	-17.6	-16.1	-17.9	-17.1	-17.4	-11.8	-12	-11.7	-11.3	-12.3
STDEV	6.827	7.153	6.612	7.785	6.597	6.73	6.225	6.034	6.467	6.185	4.982	4.557	4.709	5.211	4.595

Figure 16. Result of viewing angle

Viewing angle was almost same while performing the main task in each condition (Figure 16). In stand condition, the angle was lower than other conditions. Minus angle means, participant saw lower side compared to parallel to the horizontal line and located in eye level.

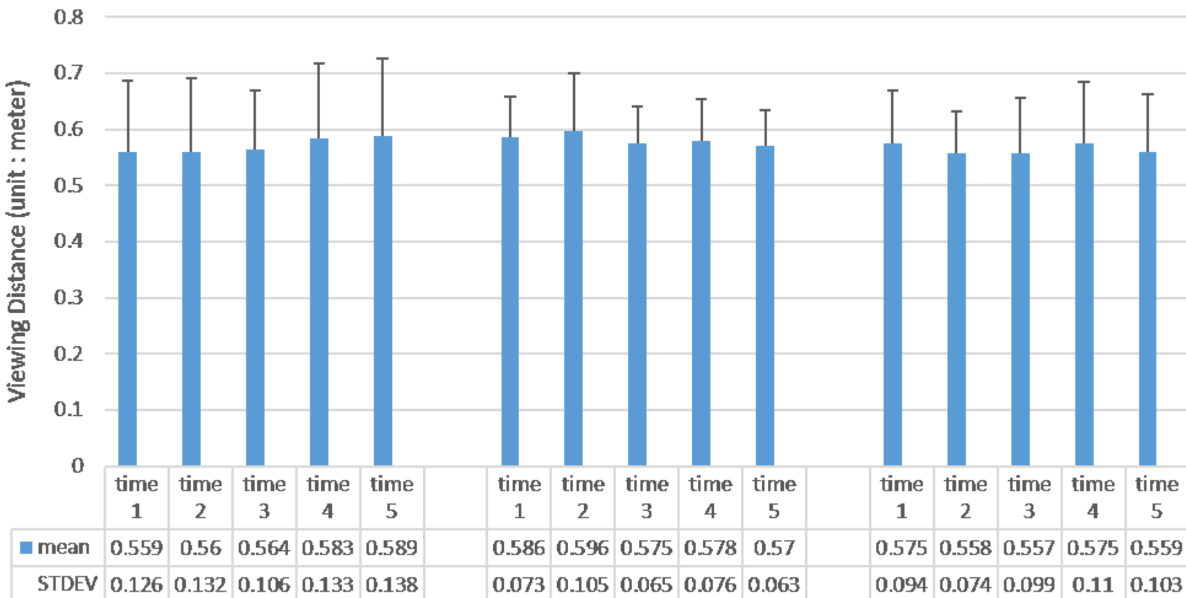
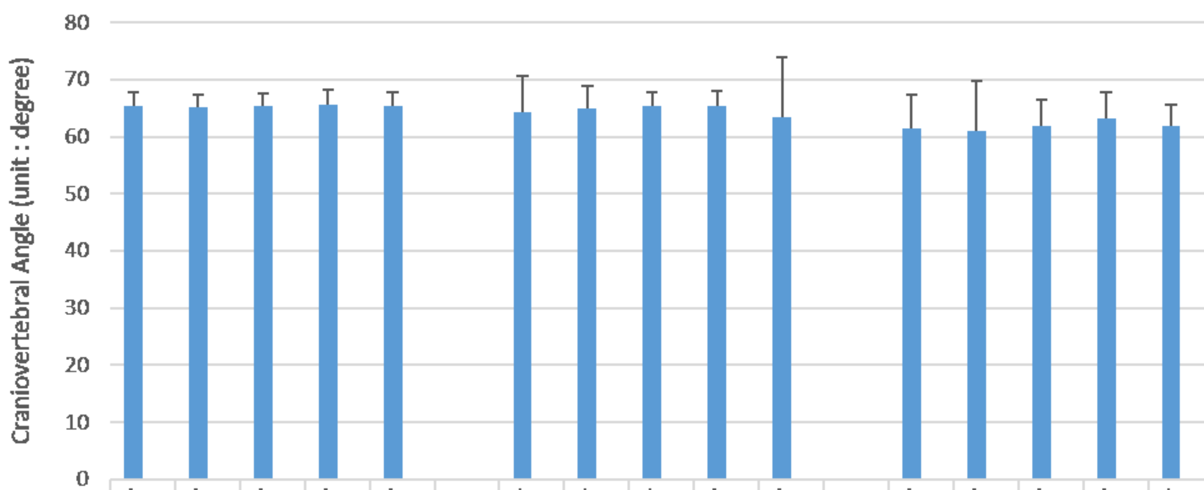


Figure 17. Result of viewing distance

Viewing distance was almost same in all condition (Figure 17). However, stand condition was the only condition shows same trend in reference posture and main task performing posture.



	time 1	time 2	time 3	time 4	time 5		time 1	time 2	time 3	time 4	time 5		time 1	time 2	time 3	time 4	time 5
mean	65.44	65.19	65.42	65.56	65.42		64.27	64.89	65.4	65.45	63.44		61.35	60.93	61.79	63.21	61.98
STDEV	2.431	2.244	2.185	2.592	2.323		6.388	3.953	2.337	2.547	10.5		5.926	8.755	4.599	4.582	3.703

Figure 18. Result of craniovertebral angle

Cranio-vertebral angle showed significant difference in chair condition only (Figure 18). It showed lower level compared to other two conditions. Lower angle means that participant's head posture towards anterior.

3.3 Muscle activities

The amplitude of gastrocnemius was highest in stand condition (Figure 19). Each condition showed significant difference (stand > stool > chair).

The amplitude of upper trapezius (UT) was highest when performing the task with a chair (Figure 20). It was found that each condition shows a significant difference in left side UT (chair > stand > stool). However, there were no difference for stool and stand condition for right side UT (chair > stool = stand).

For L2 level and L4 level signal, only stool condition and stand condition were compared. In chair condition, participants used backrest fully thus it was eliminated. The amplitude of L2 level and the L4 level was lower during performing the task with stool (Figure 21; Figure 22).

Table 5. Muscle activity result summary table

body segment	stand (mean)	stool (mean)	chair (mean)	stand (stdev)	stool (stdev)	chair (stdev)	p-value
L.UT	*2.905*	*2.264*	*3.433*	*3.176*	*2.357*	*4.400*	**0**
R.UT	*2.266*	*2.455*	*3.899*	*2.671*	*2.937*	*5.223*	**0**
L.L2	*12.291*	*10.004*		*9.760*	*5.403*		**0**
R.L2	*8.717*	*7.819*		*3.915*	*5.398*		**0.048**
L.L4	*9.227*	*6.143*		*5.052*	*3.473*		**0**
R.L4	*9.381*	*6.200*		*6.925*	*3.691*		**0**
L.GS	*7.509*	*6.251*	*5.361*	*4.818*	*4.627*	*3.543*	**0**
R.GS	*11.021*	*7.771*	*6.507*	*6.334*	*3.182*	*1.802*	**0**

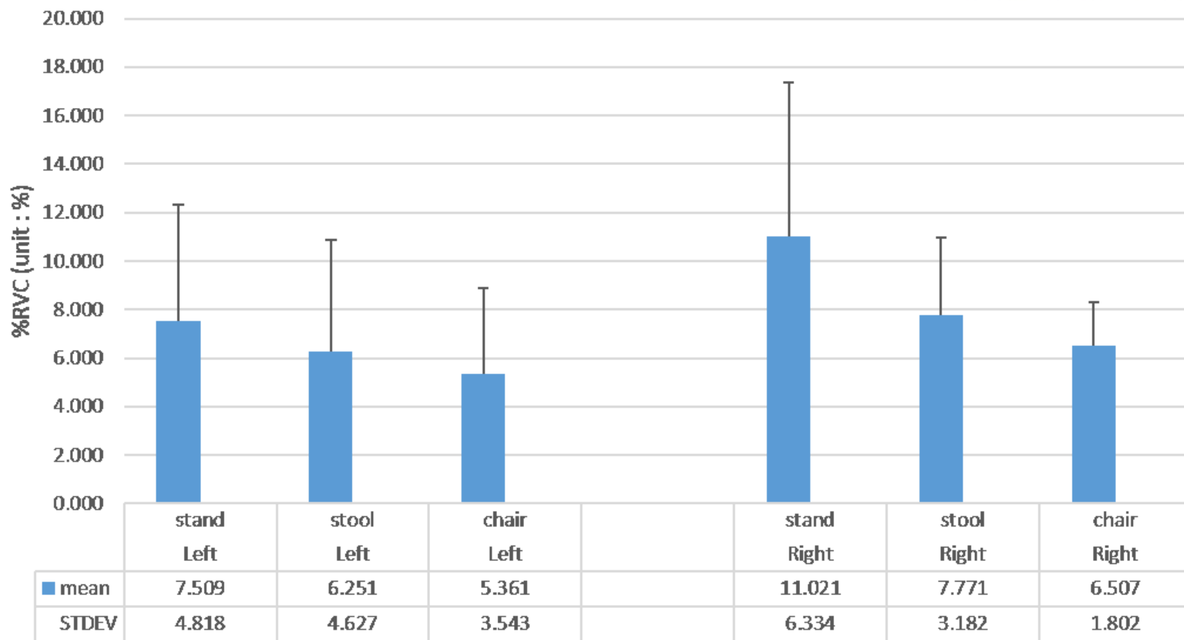


Figure 19. %RVC of Gastrocnemius

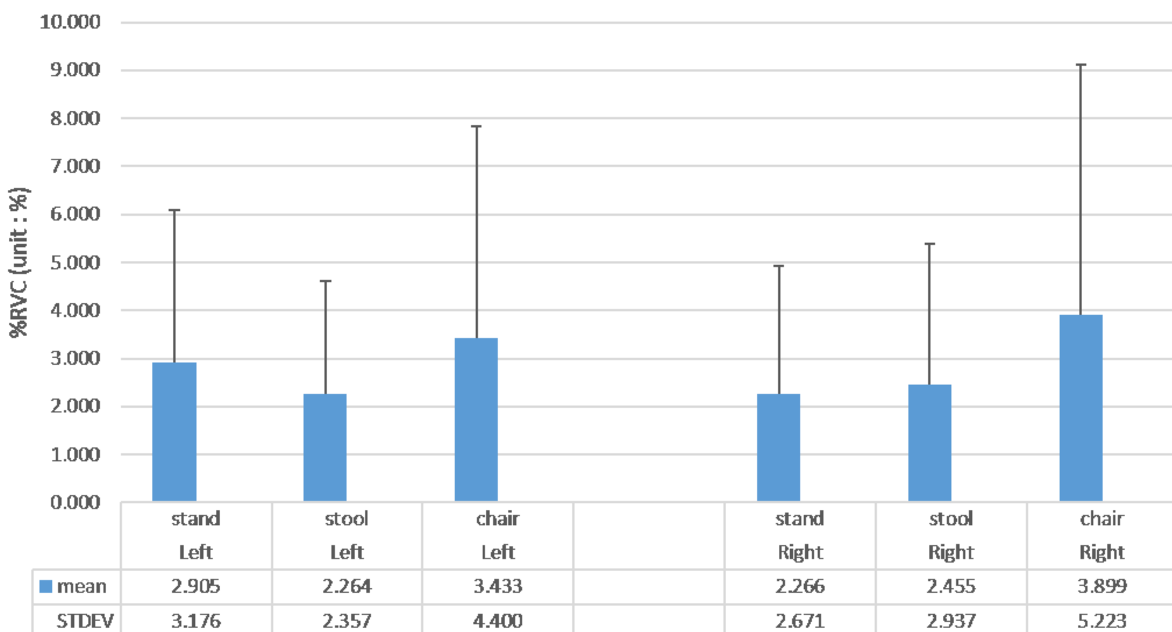


Figure 20. %RVC of upper trapezius

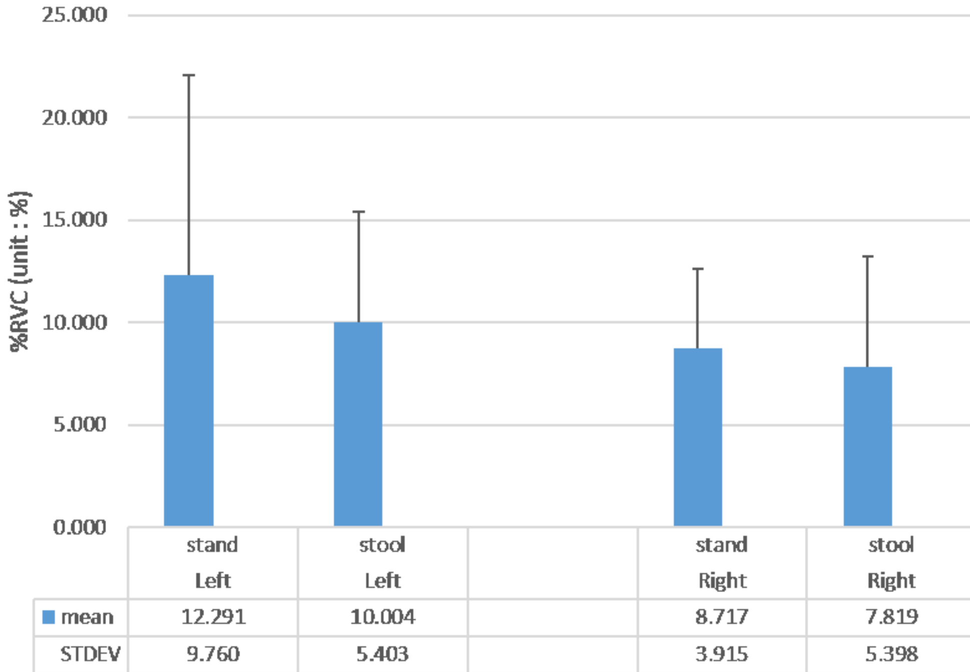


Figure 21. %RVC of L2 level

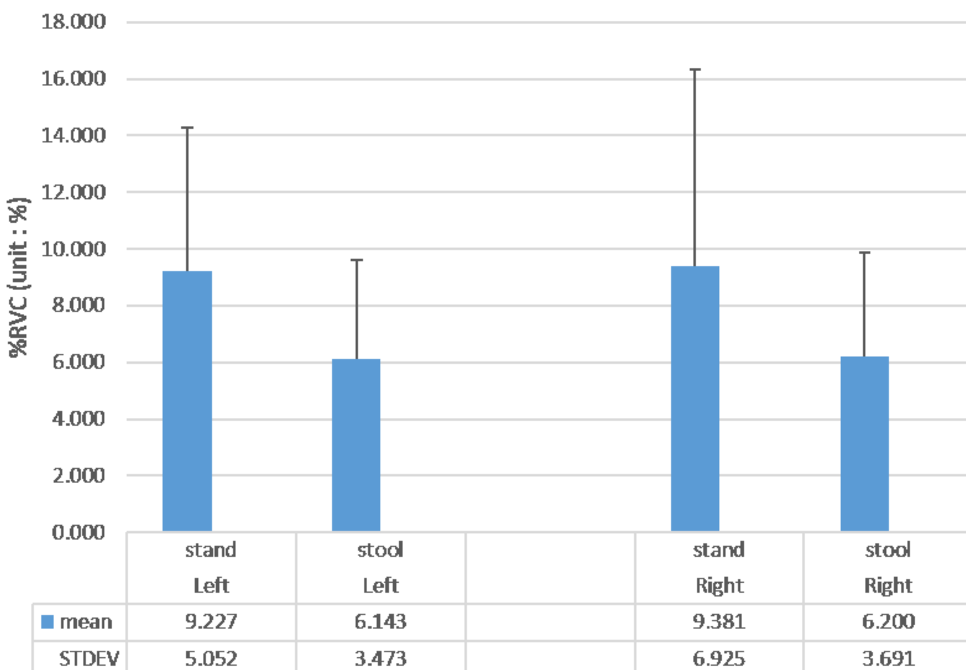
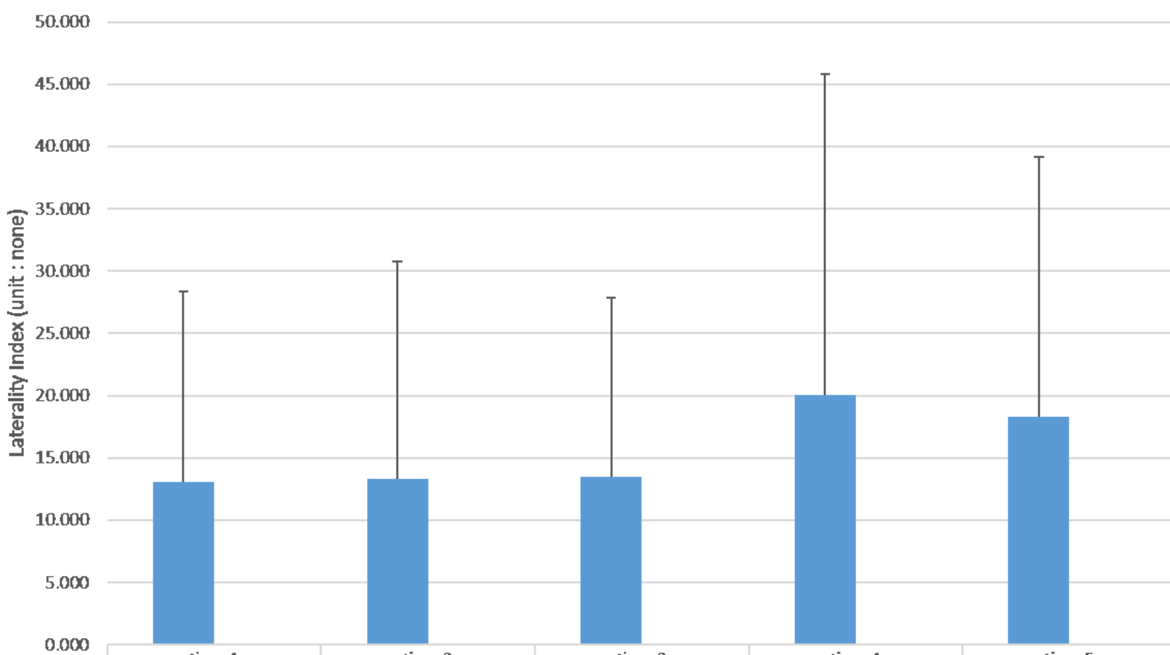


Figure 22. %RVC of L4 level

3.4 Laterality Index

Force data was analyzed for stand condition only to check posture stability. Averaged force values do not show a significant difference in time. However, standard deviation increased over task duration. Compared to reference posture's standard deviation, it was much higher when performing the task.

Laterality index data was analyzed for stand condition only. Averaged force values do not show a significant difference in time. However, standard deviation showed increasing trend over time. Compared to reference posture's standard deviation, it was much higher when performing the task (Figure 23).



	time 1	time 2	time 3	time 4	time 5
mean	13.084	13.352	13.518	20.072	18.270
STDEV	15.300	17.426	14.336	25.747	20.908

Figure 23. Laterality index

4. DISCUSSION

4.1 Subjective rating, leg circumference

Subjective rating result shows a similar trend as expected prior to the experiment. Body discomfort increased after the task, in general (Gerr et al., 2002).

There were no significant differences on both shoulders, both thigh, neck, upper back and left wrist discomfort rating results. Usually, the shoulder is considered a combination of trapezius and deltoid. It was defined as one of the two parts of the body at each side of the neck that join the arms to the rest of the body. Thus, for a participant who are not familiar with shoulder terminology as trapezius, it might be concluded as shoulder felt comfort in overall even though there is some bothersome on trapezius area.

Left wrist was the area that barely used due to participants' handedness. All of the participants use right hand as dominant hand except 3 participants (2 for left handed, 1 for ambidextrous). Given task was designed to use mouse and keyboard however there was no guidance of hand usage pattern. Most of the participant might use their right hand to control mouse not unexpectedly.

Lower back discomfort shows a significant difference between stool and chair conditions, and the existence of backrest could be the cause of this difference. When participants performed the task with a chair, they were allowed to use backrest and all of the participants used it thoroughly, relieving low back extensor muscles.

Butt discomfort was highest in stool condition, and it could be due to the differences in how participants supported their upper body weight. When using the stool, participants maintained their semi-seated posture by leaning on the stool all the time and it increased discomfort on the butt area.

The result of the thigh can be explained by butt discomfort score. In chair condition, the thigh is fully supported by seat pan, thus it does not feel discomfort much. In stand condition, thigh discomfort might be lower caused most uncomfortable area is located under knee like foot or ankle.

Calve circumference change was significantly higher for stool and chair conditions than for stand condition. This result was consistent with the results of previous research (Chester, Rys, & Konz, 2002). It was found in the previous study that sitting condition caused the largest change of leg circumference (Seo, Kakehashi, Uda, Tsuru, & Yoshinaga, 1995).

Feet discomfort rating was significantly different between conditions, with the highest discomfort increase for the standing condition. It complies with a common sense that, when person stands, the whole body weight is supported by feet only and it can cause larger discomfort than sitting postures.

4.2 Movement tracking

There were no time effects on posture data. It was only 20 minutes of recording and the duration was too short to observe the time effects. On the contrary, posture condition affected posture changes.

Cranio-vertebral angle (CVA) showed expected results. Chair condition shows lower angle compared to other two conditions. That is, Participants tend to tilt neck downward when they sit on a chair. Angle value was significantly different but not for neck discomfort subjective rating score. The difference between two conditions was 3.38 degrees to stand condition, 2.87 degrees to stool condition. The angle difference between chair condition and stand condition was too small to make difference in biomechanical burden on the cervical spine in this experiment. Future study is needed to examine whether this subtle change of this neck posture could affect neck discomfort and how much burden added to the neck. Even though there was no guideline of furniture setup, participant used standing office with proper head posture and it is explained by the result of CVA. In sitting ergonomic guide, it was suggested to keep the head upright (Government, 2013). In subjective rating, neck discomfort showed no significant difference in all conditions but if it changed the duration of the task as prolonged (more than 1 hour), it might have some significant impact on the head posture. It could be concluded to the muscular-skeletal disorder as the previous study found. Workers who spent a significant proportion of their work at a computer were at greater risk of developing neck pain (Jensen, 2003).

Viewing angle showed a significant difference between conditions. Stand showed highest and then stool followed up and chair condition shows the lowest angle. In standing condition, participants were looking down the monitor with around 25 degrees which fits ergonomic recommendation of viewing angle (Government, 2013). Standing posture naturally lead to the participant to maintain ergonomic posture. However, in the case of stool and chair, viewing angle was not proper. Visual angle was around 10 degrees in both conditions.

Viewing distance showed a different trend from viewing angle result. There was no significant difference on viewing distance even posture changed. An interesting point was a comparison to reference posture with task posture. Stand condition shows no big difference to reference posture but stool condition and chair condition shows extreme changes while conducting the experiment. The distance between head and monitor was significantly lower when performing the task. That is, participants leaned their head forward or their back posture was stooped. It may cause forward head posture, which normally prevails extreme smartphone user. Also stooped back posture can damage on our back muscle and increase sagittal vertical axis leads to a posterior pelvic shift in relation to the feet (Lafage et al., 2008).

4.3 Muscle activities

There were no significant differences between time levels in each condition, which is the same as that of previous research. The task duration is quite short to observe time effect and fatigue fully. The previous study of which duration was less than 1 hour showed the same result. Thirty-four minutes duration of the task performed using stool showed no time effect (Antle et al., 2015). There were no significant differences in muscle activation amplitude while sitting and walking for first 30 minutes (Fedorowich, Emery, & Côté, 2015) . The increasing trend of amplitude was observed in both previous studies but no significant difference within the first 1 hour.

Right, upper trapezius (UT) was activated more in chair condition than other two conditions. Handedness might affect the result. Most of the participants used the right hand as their dominant hand. Task was designed to use keyboard and mouse. Right-handed people use a mouse with their right hand. The previous study explained that both pain group and healthy group show mean 50% ADPF higher in right UT than left UT who use right hand as a dominant hand (G. P. Szeto, L. M. Straker, & P. B. O'Sullivan, 2005) . Left upper trapezius result shows a different pattern from right upper trapezius. Stand task shows the highest amplitude.

In chair condition, participants used backrest fully thus it affected the amplitude value. It exceeded more than 20%, which is an abnormal result. Thus, stand and stool condition were used to data analysis for upper back and lower back. Right L2 level, Right L4 level, Left L2 level and left L4 level's amplitude was significantly higher in stand condition. Upper back and lower back have to endure more weight while standing than when sitting on a stool as part of the weight is distributed to seat pan in stool condition. However, it does not match the result of a previous study, which showed higher amplitude for stool condition than stand condition on erector spinae (Antle et al., 2015).

Both gastrocnemius EMG results show a significant difference in order of stand, stool and chair. As expected, stand condition required more physical demand on the leg. The previous study found that posture changes could affect median frequency (MDF) of the gastrocnemius muscle (Jung et al., 2010). Standing posture shows highest MDF value and then kneeling with 120 degrees (consider same as stool condition) and then sitting posture. It was found that soleus muscle and left side gastrocnemius muscle shows higher amplitude when performing the task with standing posture (Antle et al., 2015).

4.4 Laterality Index

Force data was analyzed for only standing condition. Laterality index showed increasing trend over time. That is, alternating side of leaning body weight occurred more while continuing the task. It could be interpreted that participants were not stand straight while standing and tend to alternate weight bearing feet (leaning body weight to one side) often.

4.5 Overall Explanation

In this study, various measures of discomfort or physical risks were measured for three different office work postures. The measures included the severity of non-neutral head posture, amount of muscle activity of the shoulder, low back and leg, as well as subjective discomfort ratings. Overall, study results indicate that work in standing with periodic use of stool would be the most preferred posture for office workers, especially for work tasks that continue for 20 minutes or less.

Results of individual measures are summarized in Figure 24. Sitting posture is preferred for less leg discomfort but not recommended for neck and shoulder. For neck and shoulder, standing posture is more preferred than sitting. However, standing posture produced larger load on low back muscles than using stool and it also showed the largest stress and discomfort on the lower leg. Combining all these results, standing work posture with periodic use of stool is recommended over traditional sitting posture. The standing posture with stool will be helpful to reduce amount of cumulative fatigue and discomfort on most of body segments, especially when work task continues less than 20 minutes.

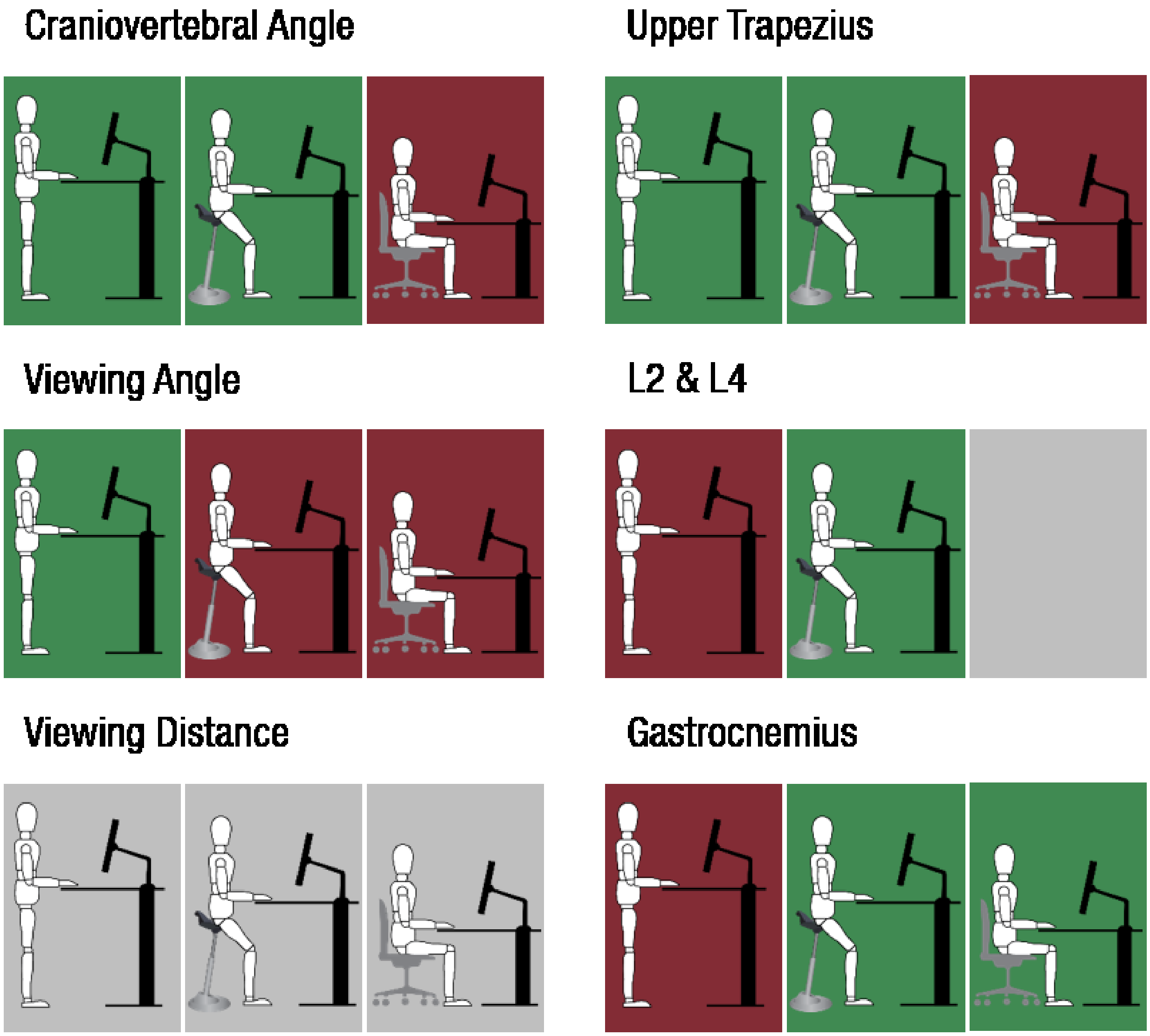


Figure 24. Recommendable for each segment's comfort

(Green : Recommendable, Red : Avoidable, Grey : No preference)

4.6 Limitations

Subjective rating score result indicates how much fatigue or uncomfortable for each body segment. However, it does not express overall tiredness. The duration of each task condition was short to observe fatigue effect. The median frequency shift is one of a method that could be an evidence of muscle fatigue and at least one hour should be given for experiment duration to observe median frequency shift (G. P. Y. Szeto, L. M. Straker, & P. B. O'Sullivan, 2005). The guideline recommended from this study result could cover only 20 minutes. If the task duration was longer, the effect of attention could also check whether it is effective or not (Korhonen et al., 2003).

Exact proper duration of standing and using stool is needed to be investigated. The previous study focused on alternating posture from standing to sitting on an office chair. However, the result of the study suggested to combine standing and sitting on a stool is a most proper combination for our muscular-skeletal system. Thus, it is needed to explore the combination for usage duration like standing for 30 minutes and then sitting on a stool for 10 minutes.

In this experiment, office environment setting like table height, monitor location, chair height was set following each participant's preference. There are specific guidelines for sitting office. Thus, it will be interesting to compare the data with keeping the posture following recent sitting office guideline in future research. In addition, task was performing documentation work with using a computer in this study. In real office environment, workers have more variation of working task.

In conclusion, more detailed topic focused experiment should have to be conducted. To explore prolonged usability for standing office, experiment duration have to be more than 2 hours. Average working hour is 7.5 (Lee, 2016) for Korean, it might be proper to setting a duration as 8 hours. If the duration increased, then observational study method should contain some special check list or measurement method. It is hard to record 8 hours of data fully with high frequency level. Thus, it should have to decrease sampling frequency and record movement with data and put trigger on time when participant changed posture like moving their leg or head.

To prove proper duration ratio, prolonged observational study should be conduct first. After checking the data and find out when data shows time effect, it is possible to select range of duration setting. For instance, there were no time effect before 2 hours of stool usage and it showed time effect after 2 hours, maximum setting duration can be 2 hours for stool condition.

The future study has to track the movement of both upper extremities and lower extremities like angle difference of thigh and calve, coordinate of each foot to check details of lower extremities movement. Also, laterality index data result indicates that force data is also important to explore newly define 'ergonomic posture'. In a future study, there should be more about foot force information like foot force on a specific area of the foot (e.g. heel, medial plantar, lateral plantar), peak force and COP.

5. CONCLUSION

This study was aimed to investigate whether standing office is ergonomic or not and to explore the possibility of using a stool as a substitute for sitting or standing office. The experiment was conducted in a laboratory with adjustable furniture. Physiological signal, body movement coordinates and foot force were collected while twenty eight participants were performing documentation works in three different posture conditions. In addition, body discomfort rating and leg circumference measurement were collected before and after each condition. The various measures of discomfort were compared between the conditions by ANOVA.

Results showed that standing posture leaded participants' posture more ergonomic. Participants tend to maintain body posture comparatively more neutrally in standing posture compared to sitting posture. However, keeping the standing posture resulted in greater muscle activity of the low back and lower leg than sitting posture, which can produce greater cumulative fatigue for prolonged work tasks. Therefore, it is recommended to alternate posture frequently, between standing and sitting on stool postures. Using stool showed better performance and more neutral posture than sitting posture.

Comparing all conditions, it was concluded that using a stool periodically when working in a standing posture could produce the least discomfort for office workers. It can guide office workers more neutral posture than sitting, and less physical stress than standing. It can also provide periodic rest or recovery moments for people who maintain prolonged standing. Results of this study can be used to make a guideline for standing office like setting table height and duration for prolonged standing and proper time for rest.

Further study needs focus on prolonged standing and sitting on stool, longer than the tested duration of this study. Especially, it is necessary to study further how lower extremities move or respond over time.

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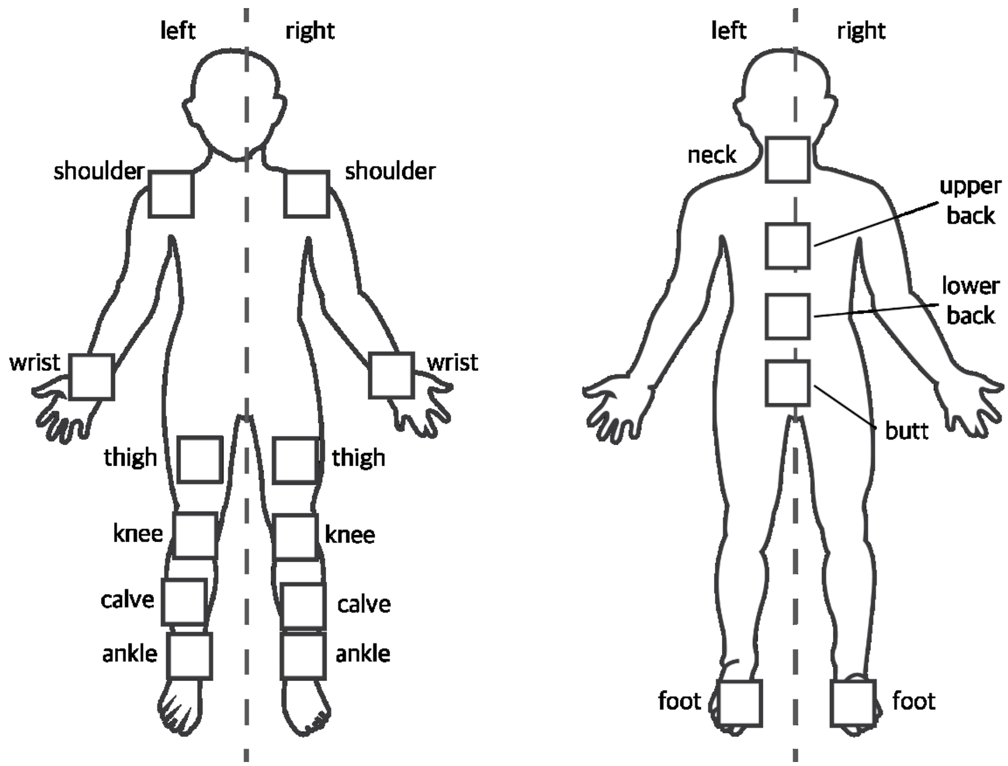
APPENDICES

APPENDIX A

Subjective rating questionnaire

Body Discomfort Rating



점수	불편도
0	전혀 불편하지 않다
1	
2	조금 불편하다
3	
4	
5	불편하다
6	
7	
8	매우 불편하다
9	
10	극도로 불편하다

APPENDIX B

Full Analysis of Variance Tables

Height adjustment score

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	0.180771	0.180771	0.090386	101.34	0
subjID	27	0.05207	0.05207	0.001929	2.16	0.008
Error	54	0.048162	0.048162	0.000892		
Total	83	0.281004				

Subjective rating

Left shoulder

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	0.381	0.381	0.19	0.12	0.888
subjID	27	58.321	58.321	2.16	1.35	0.171
Error	54	86.286	86.286	1.598		
Total	83	144.988				

Right shoulder

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	0.452	0.452	0.226	0.11	0.898
subjID	27	95.083	95.083	3.522	1.68	0.052
Error	54	112.881	112.881	2.09		
Total	83	208.417				

Neck

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	0.929	0.929	0.464	0.31	0.732
subjID	27	67.333	67.333	2.494	1.69	0.051
Error	54	79.738	79.738	1.477		
Total	83	148				

Upper back

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	16.095	16.095	8.048	3.73	0.03
subjID	27	124.571	124.571	4.614	2.14	0.009
Error	54	116.571	116.571	2.159		
Total	83	257.238				

Lower back

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	14.452	14.452	7.226	3.61	0.034
subjID	27	86.893	86.893	3.218	1.61	0.069
Error	54	108.214	108.214	2.004		
Total	83	209.56				

Left wrist

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	9.595	9.595	4.798	2.65	0.08
subjID	27	63.905	63.905	2.367	1.31	0.198
Error	54	97.738	97.738	1.81		
Total	83	171.238				

Right wrist

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	27.595	27.595	13.798	8.62	0.001
subjID	27	90.952	90.952	3.369	2.11	0.01
Error	54	86.405	86.405	1.6		
Total	83	204.952				

Left thigh

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	4.071	4.071	2.036	1.79	0.176
subjID	27	60.988	60.988	2.259	1.99	0.016
Error	54	61.262	61.262	1.134		
Total	83	126.321				

Right thigh

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	6.381	6.381	3.19	2.63	0.082
subjID	27	37.56	37.56	1.391	1.14	0.329
Error	54	65.619	65.619	1.215		
Total	83	109.56				

Left knee

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	21.595	21.595	10.798	6.5	0.003
subjID	27	49.905	49.905	1.848	1.11	0.361
Error	54	89.738	89.738	1.662		
Total	83	161.238				

Right knee

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	23.024	23.024	11.512	5.92	0.005
subjID	27	62.952	62.952	2.332	1.2	0.28
Error	54	104.976	104.976	1.944		
Total	83	190.952				

Left Calve

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	45.5	45.5	22.75	6.81	0.002
subjID	27	87.571	87.571	3.243	0.97	0.521
Error	54	180.5	180.5	3.343		
Total	83	313.571				

Right Calve

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	63.881	63.881	31.94	10.91	0
subjID	27	78.988	78.988	2.925	1	0.486
Error	54	158.119	158.119	2.928		
Total	83	300.988				

Left Ankle

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	39.5	39.5	19.75	9.48	0
subjID	27	103.143	103.143	3.82	1.83	0.029
Error	54	112.5	112.5	2.083		
Total	83	255.143				

Right Ankle

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	48.667	48.667	24.333	11.39	0
subjID	27	79.952	79.952	2.961	1.39	0.152
Error	54	115.333	115.333	2.136		
Total	83	243.952				

Left foot

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	117.214	117.214	58.607	13.18	0
subjID	27	122.702	122.702	4.545	1.02	0.459
Error	54	240.119	240.119	4.447		
Total	83	480.036				

Right foot

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	114.286	114.286	57.143	12.73	0
subjID	27	122.619	122.619	4.541	1.01	0.471
Error	54	242.381	242.381	4.489		
Total	83	479.286				

Butt

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	72.071	72.071	36.036	8.54	0.001
subjID	27	66.893	66.893	2.478	0.59	0.933
Error	54	227.929	227.929	4.221		
Total	83	366.893				

Left Circumference

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	148.67	148.67	74.33	4.84	0.012
subjID	27	786.95	786.95	29.15	1.9	0.023
Error	54	829.33	829.33	15.36		
Total	83	1764.95				

Right Circumference

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
type	2	169.02	169.02	84.51	6.87	0.002
subjID	27	824.33	824.33	30.53	2.48	0.002
Error	54	664.31	664.31	12.3		
Total	83	1657.67				

Posture change

Craniovertebral angle

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	943.42	942.65	471.33	21.56	0
subjID	26	1627.13	1627.13	62.58	2.86	0
Error	374	8176	8176	21.86		
Total	402	10746.56				

Viewing angle

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	9472.52	8835.04	4417.52	179.4	0
subjID	4	195.84	192.37	48.09	1.95	0.101
Error	27	8270.15	8270.15	306.3	12.44	0
Total	358	8815.32	8815.32	24.62		

Viewing distance

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	0.008989	0.006036	0.003018	0.48	0.622
subjID	4	0.011964	0.016024	0.004006	0.63	0.641
Error	27	1.765969	1.765969	0.065406	10.3	0
Total	358	2.272798	2.272798	0.006349		

EMG

Left Upper Trapezius

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	0.009622	0.009622	0.004811	18.21	0
subjID	27	0.421087	0.421087	0.015596	59.03	0
Error	474	0.125238	0.125238	0.000264		
Total	503	0.555946				

Right Upper Trapezius

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	0.021216	0.021216	0.010608	31.19	0
subjID	27	0.48815	0.48815	0.01808	53.16	0
Error	474	0.161198	0.161198	0.00034		
Total	503	0.670564				

Left L2

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	1	0.03338	0.03338	0.03338	19.64	0
subjID	27	1.705252	1.705252	0.063157	37.15	0
Error	307	0.521862	0.521862	0.0017		
Total	335	2.260495				

Right L2

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	1	0.003834	0.003834	0.003834	3.93	0.048
subjID	27	0.42267	0.42267	0.015654	16.03	0
Error	307	0.299728	0.299728	0.000976		
Total	335	0.726232				

Left L4

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	1	0.072189	0.072189	0.072189	86.49	0
subjID	27	0.409115	0.409115	0.015152	18.15	0
Error	307	0.256251	0.256251	0.000835		
Total	335	0.737555				

Right L4

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	1	0.06517	0.07291	0.07291	45.37	0
subjID	27	0.463187	0.463187	0.017155	10.67	0
Error	305	0.490163	0.490163	0.001607		
Total	333	1.01852				

Left Gastrocnemius

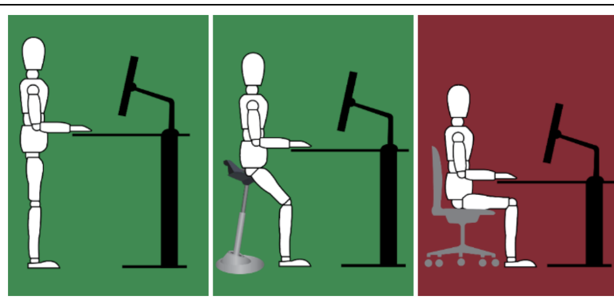
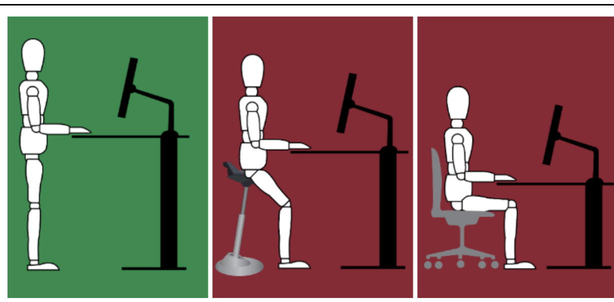
Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	0.04663	0.04663	0.023315	52.48	0
subjID	23	0.454817	0.454817	0.019775	44.51	0
Error	406	0.180375	0.180375	0.000444		
Total	431	0.681822				

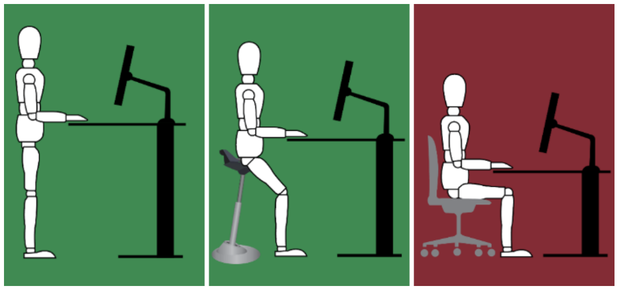
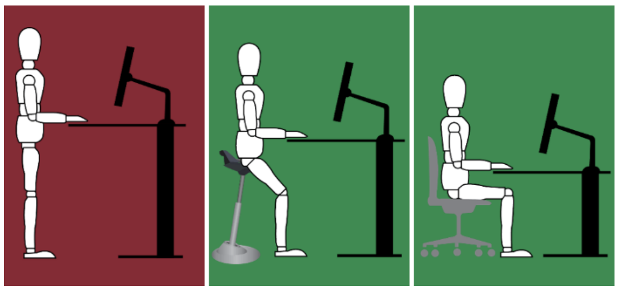
Right Gastrocnemius

Source of Variance	Degree of Freedom	Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F	P-Value
task	2	0.174661	0.174661	0.087331	82.18	0
subjID	27	0.431429	0.431429	0.015979	15.04	0
Error	474	0.503729	0.503729	0.001063		
Total	503	1.109819				

APPENDIX C

Office usage protocol suggestion pictogram

factor	Pictogram	Recommended group
cranio -vertebral angle		Standing type / Sit-Stand type ■ FHP patient Chair type ■ Non-FHP patient
Viewing Angle		Standing type / Sit-Stand type ■ FHP patient Chair type ■ Non-FHP patient

Upper trapezius		Standing type / Sit-Stand type ▪ Neck-shoulder symptom Chair type ▪ Healthy upper extremities
Gastroc -nemius		Standing type ▪ Healthy lower extremities Sit-Stand type / Chair type ▪ Leg pain group

- Green color means more ergonomic for 20-minutes duration usage
- Red color means that has more risk than other posture condition.
- Choose your preference according to your muscular-skeletal health condition